
UNIT 5 LIPIDS

Structure

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5.1 INTRODUCTION

If somebody discovers that you have some knowledge of nutrition, you will be promptly shouted with two questions, first, “Oh! You really can tell how much to eat?” and second, “Tell me which oil to eat ‘X’ or ‘Y’?” In view of learning about other macronutrients in previous units on carbohydrates and proteins, let us now embark to learn more about lipids.

This unit will detail on types and functions of fats and oils, their requirements and significance in health and disease. Changing dietary patterns can sometimes lead to higher risk of some diseases. On the other hand, prudent decisions on qualitative and quantitative aspects of fat can in fact prevent the onset of certain diseases associated with contemporary lifestyles.

At the end of going through this unit, you must do self assessment and recapitulate various dimensions of knowledge pertaining to dietary fats and oils. You will acquire adequate skills and confidence to prescribe fats and oils to any community. Tips will be given to reduce fat intake from human dietaries and will come handy in counseling patients of obesity, heart diseases, diabetes and cancer. You will be able to modify fat intake of patients with fat malabsorption and liver diseases. We hope you find this unit relevant and handy.

Objectives

After studying this unit, you should be able to:

- recommend necessary modifications in types and amount of dietary fat keeping in mind visible and invisible fat, fatty acid composition and effect of dietary fat on lipid profile,

- critically analyze the implications of excessive fat intake and changing lifestyle, and
- generate guidelines for use of fats and oils in diet and selection of dishes to avoid excessive intakes.

5.2 FATS: SOME BASIC FACTS

Let us begin our discussion on lipids with a self assessment exercise given in Box 5.1.

Box 5.1	Self Assessment
Did you know? 1) Fats are essential in diets to facilitate satiety, high-energy intakes, and absorption of fat-soluble vitamins and provide essential fatty acids. 2) Anti-oxidant requirements increase with PUFA rich oil. 3) Vegetable oils contain no cholesterol. 4) Green leafy vegetables, some spices and cereal pulse diet can provide linolenic acid. 5) Vegetable oils contain as many calories as animal fats. 6) Oils are rich source of PUFA and only 3 tsp/day are needed in an adult diet. 7) Triglycerides are the main form of fat found in diet. Diets, which provide excess calories, fat and cholesterol elevate blood lipids. 8) Excess fat in diet increases the risk of obesity, heart diseases and cancer. 9) Serum cholesterol measurements are important even before 40 years of age. The ill effects of dietary fat are initiated early in life. Lipid levels should be assessed to screen children for risk anyway. 10) Fresh vegetables and fruits are fat-free and contain phytochemicals, which are cardio-protective. 11) Cholesterol is formed in foods of only animal origin. Animal foods also have high amount of invisible fats, rich in saturated fatty acids. 12) Fish is an excellent source of long chain n-3 fatty acids, which are cardio-protective. 13) Deep fried snacks eaten in quick service restaurant are likely to be rich in trans- fatty acids, which increase blood cholesterol. 14) Fat present in whole milk, soyabean, peanuts and flesh foods is called invisible fat and contribute to total fat intake substantially. 15) Exercise can improve lipid transport agents in blood. It keeps body fat low. (Read about body fat in inset) <i>If you did not know some of these facts, encircle it. Read this chapter and check again. You can score out of 15 marks yourself before and after reading this unit!</i>	

Now then, *are you interested in knowing about body fat?* Yes, so let us proceed with our discussion.

Let us begin our discussion with a review on what does it actually means to be fat or over fat or being obese. We have studied this concept in Unit 2 earlier. Here let us revise the concept again.

Obesity is best classified in adults based on Body Mass Index (BMI) classification. BMI, you already know, is *a measure of body fat based on height and weight*. However, in clinical practice, body fat (BF%) measurements are also gaining importance. Body fat was always measured in sports subjects to monitor level of practice and physical fitness. Body fat is generally considered a predictor of storing unused fuels when energy intake exceeds energy expenditure. In initial stages, the net body weight may be within the normal range but body fat exceeds. However, level of body fat also depends on the level of physical inactivity, sex, age and genetic predisposition.

In adults, the body fat $\geq 24\%$ and in women, $\geq 27\%$ fat is considered to be overweight over fat. However, these cutoffs are used for pure academic study rather than actually classifying obesity. Classification of obesity based on BMI and BF% do not necessarily overlap and BMI has many more clinical correlates to risk of diseases than BF%. Generally, BF% per se correlates best to physical activity levels.

Do you know how body fat can be measured? The conventional golden method of measuring BF% is by *under water weighing*. Difference of weight in air and in water gives density, from which the body fat is computed. As these methods limits field application, two methods have been used extensively:

- 1) *Skin fold method*, and
- 2) *Impedance method*.

Let us learn about these.

- 1) *Skin fold method*: The skin fold method utilizes predication of body fat from sum of three or four skin folds (at biceps, triceps, sub scapular, suprailiac regions). Specific prediction equations for each age category and both sexes are available as presented in Table 5.1.

Table 5.1: Age and sex adjusted equation by Durnin and Womersley (1974) for calculating body fat %

Age of Women (in years)	Equation
30 - 39	$D = 1.1423 - 0.0632 \times (\text{Log } \Sigma)$
40 - 49	$D = 1.333 - 0.0612 \times (\text{Log } \Sigma)$
50 +	$D = 1.339 - 0.0645 \times (\text{Log } \Sigma)$

where, D = body density (g/ml)

(Log Σ) = log of summation of four skin fold i.e.: biceps, triceps, sub scapular, suprailiac

$$\text{Fat mass (kg)} = \text{body weight (kg)} \times \frac{4.95 - 4.5}{D}$$

$$\text{Body fat (\%)} = \frac{\text{Fat mass (kg)}}{\text{Body weight (kg)}} \times 100$$

$$\text{Fat free mass (kg)} = \text{Body weight (kg)} - \text{Fat mass (kg)}$$

Similar equations are also available for men.

- 2) *Impedance method*: This method can give entire body composition like total body water (TBW), fat free mass (FFM) or lean body mass (LBM), fat mass (FM) and body fat (BF%) and body mass weight (kg/lb). The analyzer requires data on height and correction for weight of clothing. It computes wt/ht^2 to give BMI also. The principle of this method is to pass a small electric current through the body and the subject stands on electrodes as on a weighing scale. The impedance is printed with body composition analysis data.

Many more methods have been used in research but these three methods (*under water weighing*, *skin fold method* and *impedance method*) have been widely used. The

other methods like *dual energy X-ray absorptiometry (DXA)*, *Magnetic Resonance Imaging (MRI)* and *Computed Tomography (CT)* are accurate and can find fat distribution. The method has a disadvantage of being expensive, involves radiation exposure and is not suitable for field work.

Having learnt about some basic facts about fats and about methods of assessing body fat, let us now study the types and significance of fats/lipids in human diet. We must know the amount necessary for optimal functioning of the body. We must also know if we eat in excess than the suggested requirements, what are the implications on long term health of the human being. These are a few issues covered in the following sections.

5.3 TYPES OF FATS AND ITS METABOLISM

The type of fat consumed by a person is solely dependent on:

- which oil(s) the family purchases,
- eating out pattern, and
- choice of foods eaten outside or purchased and brought home to be consumed by the family.

Consider the following situation. In a household, say the family (four members) consumes one kg packet of ghee and 2-3 litres of different vegetable oils, like one litre bottle of mustard oil and 5 litre can of groundnut/sunflower oil at any given time. An adolescent boy of this family consumes one breadroll everyday from canteen and upto three pastries/week. He loves to eat besan coated fried peanuts during TV watching. Further, his father brings aloo-kachori while returning home from office to eat at teatime atleast twice a week. Hence the boy lands up consuming 5-6 different sources of fats and oils. Can you tell how?

Well, any diet comprises of *visible fat* and *invisible fat*. *Visible fats* are the *fats and oils used as such at the table or used for cooking*. For example, vegetable oils, ghee, salad dressing, mayonnaise, butter, cream etc. *Invisible fats are present naturally as an integral component of different foods*. Hence, flesh foods, whole milk, peanuts, soyabean, nuts and oilseeds, spices etc. have a high invisible fat content. Cereals contain only 2-3% of invisible fat but they constitute bulk of Indian diets and thus contribute significantly to overall fat intake.

Visible fats can be derived from both *plant* and *animal origin*. The fats traditionally used in India are reasonably region or state-specific. Ghee is popular among all affluents and during festivals, whereas, vanaspati is consumed by lower middle class. Generally, *groundnut oil* is popular in *Western* and *Southern* parts of India; *coconut oil* in *Kerala*, *rapeseed* and *mustard oil* in *North* and *East* i.e. West Bengal, Punjab and Jammu and Kashmir; *safflower oil* is consumed in *Northern Karnataka* and *Southern Maharashtra*. Newer sources of oils are becoming increasingly popular like rice bran oil, palmolein and soya oil. Apart from this, cotton seed oil, sesame oil, castor oil and nigerseed oil is also produced in India. Solvent Extractors Association of India reported in March 2003 that the per capita availability of fats and oils is 15-17 g/day, of which 10-12 g is vegetable oils.

So we have just seen that a wide variety of fats/oils are consumed. Do you know how these fats/lipids are classified? Let us read and find it out in the following sub-section.

5.3.1 Classification of Fats and Fatty Acids

You must be wondering in this unit on lipids why we are talking about fats and oils and not using the term lipids. Definitely, you may also recall reading earlier in the Nutritional Biochemistry Course, in Unit 2, that when we talk about fats/oils, chemically we are referring to lipids. *Lipids which are solid at room temperature are referred to as fats and those which are liquid are oils.* Lipids are more apt when referred to all of them. However, in nutrition textbooks, fats and oils are referred in diets and lipids are referred in body fluids, like, serum lipid profile.

Chemically, lipids are the organic molecules poor in oxygen content, soluble in organic solvents but insoluble in water. They are classified as:

- Simple lipids
- Compound lipids
- Derived lipids

Let us get to know each of these.

- *Simple lipids* are fatty acid esters of glycerol, called *triacylglycerols* or *triglycerides* (for e.g. fats and oils) or higher alcohols (for e.g. waxes). Triglycerides are the major form of lipids present in human dietaries. They are the major sources of fatty acids to the body. Look up Unit 2 in the Nutritional Biochemistry Course for the structure of triglycerides.
- *Compound lipids* are the simple lipids which combine with proteins (lipoproteins), carbohydrates (glycolipids), phosphates (phospholipids) etc.
- *Derived lipids* refer to fatty acids, glycerol, cholesterol and other derived compounds including fat-soluble vitamins, hormones and bile. Man can synthesize cholesterol in the body but some amount also comes from the diet. Cholesterol is present only in foods of animal origin.

Nature of fatty acids present in the triglyceride determines the physico-chemical properties and biological significance of the lipid. Triglycerides made up of saturated fatty acids are solids at room temperature and are called *fats*. If unsaturated fatty acids are present, they are liquid at room temperature and are called *oils*. What do we mean by *saturated* and *unsaturated* fatty acids? Certainly, you must be aware of this! Let us understand fatty acids in a little more detail.

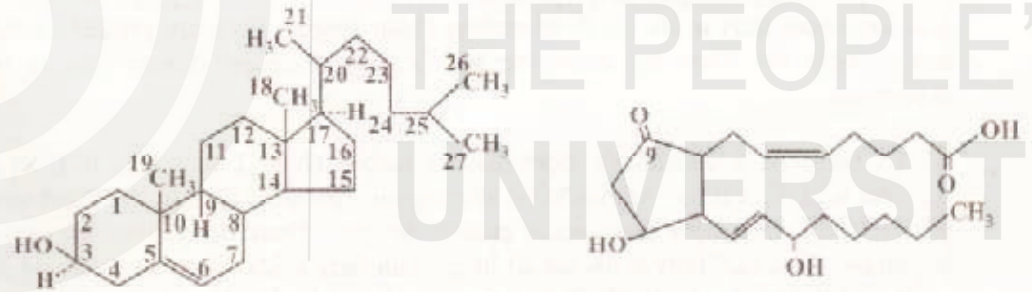
The fatty acids can be discussed under following heads:

- Saturated and Unsaturated,
- Short chain, medium chain and long chain,
- Essential fatty acids, and
- Trans-fatty acids.

These categories are more suitable from the nutritional standpoint of view and are not essentially exclusive. The fatty acid per se may overlap in these categories but their applications in normal and therapeutic diets warrants this classification. For example, a dietitian prescribes medium chain triglycerides in liver disorders. On the other hand, saturated fatty acid intake should be limited in normal diets for prevention of heart diseases.

So, then, let us now get to know them.

Saturated fatty acids (SFA) are those fatty acids which lack double bond, example palmitic acid (16:0), stearic acid (18:0) and lauric acid (12:0). For your convenience, we have given the structure of some lipids in Box 5.2. Look up the structure of palmitic and stearic acid. Sources of SFA are animal fats, coconut oil, palm oil and vanaspati. Refer to Table 5.2 which gives examples of SFA.

Box: 5.2 Structure of Lipids		
• Saturated Fatty Acids (SFA)		
$\text{CH}_3(\text{CH}_2)_{14}\text{COOH}$	Palmitic acid	(16:0)
$\text{CH}_3(\text{CH}_2)_{16}\text{COOH}$	Stearic acid	(18:0)
Monounsaturated Fatty Acids (MUFA)		
$\text{CH}_3(\text{CH}_2)_7\text{CH}=\text{CH}(\text{CH}_2)_7\text{COOH}$	Oleic acid	(ω 9, 18:1)
Polyunsaturated Fatty Acids (PUFA)		
$\text{CH}_3(\text{CH}_2)_4\text{CH}=\text{CH}-\text{CH}_2-\text{CH}=\text{CH}(\text{CH}_2)_7\text{COOH}$	Linoleic acid	(ω 6 18:2)
$\text{CH}_3(\text{CH}_2)\text{CH}=\text{CH}-\text{CH}_2-\text{CH}=\text{CH}-\text{CH}_2-\text{CH}=\text{CH}-(\text{CH}_2)_7\text{COOH}$	Linolenic acid	(ω 3 18:3)
Triglyceride ($\text{R}_1, \text{R}_2, \text{R}_3$ are fatty acids)		
CH_2COOR_1		
CH_2COOR_2		
CH_2COOR_3		
Lecithin (contains glycerol R_1 and R_2 fatty acids, phosphoric acids and choline)		
CH_2COOR_1		
CHCOOR_2		
O		
$\text{CH}_2\text{-O-P-O-CH}_2\text{-CH}_2\text{-N}^+(\text{CH}_3)_3$		
O		
CH_2COOR_3		
		
Cholesterol ($\text{C}_{27}\text{H}_{46}\text{O}$)		
Prostaglandin F_2		

Note: 18:1 stands for carbon chain of 18 and one double bond; ω 9 stands for counting 9 carbons from methyl end till the double bond-read as ω 9 on n-9.

Monounsaturated fatty acids (MUFA) contain a single double bond (as shown in Box 5.2). The examples include palmito oleic acid (16 : 1) and oleic acid (18 : 1). Its sources are olive oil, canola oil, groundnut oil, rice bran oil, red palm oil and sesame oil (Refer to Table 5.2).

Polyunsaturated fatty acids (PUFA) contain more than one double bond in their structure. These double bonds can be counted from $-\text{COOH}$ end or $-\text{CH}_3$ end (refer to Box 5.2). 18:2^{9,12} stands for linoleic acid which is C-18 stearic acid derivative having two double bonds between carbon 9 and 10, as well as, carbon 12 and 13. Hence, when we count from CH_3 end, the double bond appears at carbon number 6. We therefore also call linoleic acid as omega (ω -6) (or n-6) fatty acid. *Linoleic* acid (C18:2, n-6) and *Linolenic* acid (18:3, n-3) are essential fatty acids, which are not synthesized in the body. They are obtained from oils rich in PUFA content. PUFA is present mostly in vegetable oils but fish oil is particularly rich in PUFA.

Table 5.2: Fats and oils and their fatty acids

Saturated Fatty Acids	Monounsaturated Fatty Acids	Polyunsaturated Fatty Acids	
		Linoleic (n-6) (LA)	Linolenic (n-3)* (ALA)
Ghee/Butter	Olive (77%)	Low (<10%):	Mustard oil (10%)
Coconut (89%)	Canola (58%)	Red Palm oil	Canola (8%)
Palm kernel (86%)	Groundnut (50%)	Palmolein	Soyabean oil (5%)
Palm oil (51%)	Rice bran oil(45%)	Olive oil	Rice bran oil (1%)
Vanaspatti (24%)	Sesame (42%)	Medium(< 35%):	
	Palmolein	Groundnut oil	
	Red Palm oil	(40%)	Rice Bran oil
		Sesame oil	
		High	
		Safflower oil	
		Sunflower oil	
		Cottonseed oil	
		Soyabean oil	
		Sesame oil	
		Corn oil	

*Other food sources: wheat, bajra, blackgram, cowpea, rajmah, soyabean, green leafy vegetables, fenugreek and mustard seeds and fish. Fish also contains C20 and C22, n-3 PUFA.

() Parenthesis indicates g/100g of that category of fatty acids.

Short chain fatty acids are less than six carbon chain length i.e. smaller than caproic acid (C6:0). Butter contains small chain fatty acids. They are also obtained during fermentation.

Medium chain fatty acids are 6-10 carbon chain length. They are present in butter and coconut oil (Refer to Table 5.2). They are recommended in liver disorders due to ease in their absorption.

Long chain fatty acids contain more than 12 carbon chain. Lauric acid (C12:0) and myristic acid (C14:0) are known to be atherogenic. Palmitic acid (C16:0) and stearic acid (C18:0) are major fatty acids present in diet. Their derivatives are equally important. Essential fatty acids are all long chain fatty acids. What are essential fatty acids and their roles in our body? Let us read and find out next.

Essential Fatty Acids (EFA)

There are two essential fatty acids – *linoleic* and *linolenic acid* as mentioned above. Their structures are depicted in Box 5.2. They are both 18 carbon compounds with more than one double bond – *linoleic acid* (n-6) C18:2^{9, 12} while *linolenic acid* is (n-3) C 18:3^{9, 12, 15}. The human cell cannot place double bonds between ninth carbon and methyl end hence, omega - 3 (n-3) and omega-6 (n-6) fatty acids need to be derived from the daily diets. *Linoleic acid* (LA) (n-6) can be lengthened to C-20 and dehydrogenated to give *arachidonic acid* (AA) (C20:4^{5,8,11,14}). *Linolenic acid* (n-3) (ALA) can be lengthened and dehydrogenated to C20 and C22 compounds like *eicosapentaenoic acid*, EPA (C20:5) and *docosahexaenoic acid*, DHA (C22:6). These are known to be cardio-protective and are also present in fish oil (Refer to Table 5.2).

Omega 3 and Omega 6 fatty acids are part of vital body structures, perform important role in immune system, formation of cell membrane and produce hormone-like compounds called *eicosanoids*. These hormone-like compounds include prostacyclins, prostaglandins, thromboxanes and leukotrienes. These compounds are potent regulators

of vital body functions like blood pressure, child birth, blood clotting, immune response, inflammatory responses and stomach secretions.

Note: Aspirin is known to inhibit blood clotting because it blocks synthesis of eicosanoids. Physicians prescribe small doses of aspirin on regular basis for patients at high risk of heart attack.

Next, we move on to understand what do we mean by *trans-fatty acids*, how these are produced and what are its sources.

Trans fatty acids (TFA)

Plant derived fats and oils contain cis-fatty acids. You may recall reading about the cis and trans isomers in the Nutritional Biochemistry Course. Cis and trans-isomers, we learnt, have the same chemical formula but different chemical structure and properties.

Trans-fatty acids are produced when vegetable oils are hydrogenated to make margarine, partially hydrogenated vegetable shortening and vanaspati. Hence, major sources of trans-fatty acids to human diets are commercially baked products, deep fried snacks in vanaspati and mithai. Small amount of trans-fatty acids are present in milk fat formed by bacterial conversion of cis into trans-fatty acids in cow's stomach. Metabolically, trans-fatty acids and saturated fatty acids raise blood cholesterol levels.

Before moving on to the understanding of digestion of fats in our body, let us review what we have learnt so far.

Check Your Progress Exercise 1

- 1) Explain the relevance of measuring body fat. Name the methods that are used to measure body fat. Give the equation for calculating BF%.

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- 2) What do you mean by visible and non-visible fats? Give examples.

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- 3) Classify lipids, giving examples.

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4) What are EFAs? Give examples and enumerate their functions in our body.

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5) How are trans-fatty acids produced? What are its sources?

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Having studied about the classification of fats above, next we shall review the digestion, absorption and transport/utilization of fat in the body.

5.3.2 Digestion of Fats

The enzyme in human gut which is responsible for fat digestion is '*lipase*'. Lipase is secreted by both stomach and pancreas. In stomach, the dietary lipids get liquidized in presence of heat and gastric contractions. Gastric lipase can only hydrolyze 30% of triglycerides comprising short and medium chain length. Hence, the lipolytic activity of stomach is not important. Only milk fat which contains some short and medium chain fatty acids tends to be hydrolyzed. These short chain fatty acids can then get absorbed through stomach wall into portal vein.

Mostly diets have fats which provide long chain fatty acids. Long chain fatty acids entirely depend on emulsification by bile in gut. The *pancreatic juice* and the *bile* are secreted together through common bile duct in the duodenum. Bile emulsifies fat into hydrophilic micelles making lipase more efficacious to act. Pancreatic lipase is specific to hydrolyze primary ester linkages at carbon position 1 and 3 of glycerol in a triglyceride. After this action, mixture of products is obtained for absorption in jejunum. The products are – glycerol, fatty acids, monoacylglycerol and diacylglycerol. *Phospholipases* act on phospholipids giving glycerol, fatty acid, lysolecithin etc., while *cholesterol esterase* acts on esterified cholesterol to give free cholesterol and fatty acids. Let us now know how after digestion these products are handled for absorption.

5.3.3 Absorption of Fats

After digestion, only 25% of triglycerides are broken completely to glycerol and fatty acids. Major digestion product is *2-monoacylglycerol*. This is because lipase can hydrolyze ester linkages at the positions 1 and 3 of glycerol preferentially. The 2-monoacylglycerol, fatty acids and 1-monoacylglycerol leave the oily phase and diffuse into micelles consisting of bile salts, lecithin and cholesterol into the aqueous phase of intestinal lumen towards brush border of the mucosal cell.

The utilization of free fatty acids is by activation of fatty acids and glycerol inside the mucosal cell to resynthesize triacylglycerol. These triacylglycerols and phospholipids, cholesterol esters, cholesterol and small amount of protein form chylomicrons. What are '*chylomicrons*'? Look up Unit 2 in the Nutritional Biochemistry Course now. Yes, so you now know that chylomicrons are basically *lipoprotein molecules which are*

water miscible. They are poured into lymphatic vessels through lacteals to reach the liver.

Hence long chain fatty acids of more than 10 carbon chain, phospholipids and cholesterol are absorbed in lymphatic vessels. Short-chain and medium-chain fatty acids are absorbed without bile emulsification into portal vein as unesterified acids. Plant sterols, fat-soluble vitamins A, D, E and K are all absorbed like long chain fatty acids.

In liver disorders, long chain fatty acids may be replaced by medium chain triglycerides for better tolerance and increasing energy intake. In deficiency or absence of adequate bile, long chain triglyceride absorption may or may not be affected, hence fat is given to patients of liver disorders as per their tolerance. We will learn more about this in the Clinical and Therapeutic Nutrition Course (MFN-005) in Unit 15.

Bile itself undergoes reabsorption to be recycled 6-10 times a day. This is called 'enterohepatic circulation of bile'. In patients of familial hypercholesterolaemia, more bile gets reabsorbed. Look up Unit 7 in the Nutritional Biochemistry Course (MFN-002) to get to know more about familial hypercholesterolaemia. Excretion of bile is an important route of eliminating endogenous cholesterol. As bile is derived from cholesterol inside the liver cells, the loss of bile from body would mean utilizing cholesterol for bile synthesis. Clinically, hypercholesterolaemia may be treated by interrupting enterohepatic circulation of bile. Drugs can be given to prevent reabsorption of bile so that more and more endogenous cholesterol converts into bile and gets eliminated from the system.

In the previous sections, we learnt how fats and lipids are digested and absorbed in various forms – short chain, medium chain and long chain fatty acids. Let us now try to understand how these are transported and stored in our body.

5.3.4 Transport and Storage of Fats in the Body

The chylomicrons circulate in blood for about 2 hours or more after the meal. They are acted upon by lipoprotein lipase giving free fatty acids (FFA) and glycerol. Muscles, adipose and other cells pick up FFA and utilize them to derive energy. Muscles derive energy but adipose cells re-esterify FFA with glycerol to store as triacylglycerol.

If a body consumes more energy than expended, liver uses the carbon skeletons of protein, carbohydrate and alcohol to synthesize lipids including cholesterol. Hence, liver is lipogenic whereas adipose cells store lipids rather than synthesizing these.

Liver decides transport of lipids in aqueous phase of blood. It coats the triacylglycerols and cholesterol with proteins and phospholipid shell (similar to chylomicrons), synthesizing *very low density lipoproteins (VLDL)*. VLDL loses fatty acids after the action of lipoprotein lipase in blood and then its density increases. These are called '*intermediate density lipoproteins (IDL)*' and '*low density lipoproteins (LDL)*'. LDL contains all the cholesterol present in VLDL having therefore a higher cholesterol/triacylglycerol ratio rather than VLDL and IDL. LDL is therefore referred to as 'bad' cholesterol and is strongly associated as a risk factor of heart diseases. LDL delivers its contents into the cell through LDL receptors. Liver contains 50-75% of LDL receptors in the body. Liver hence plays an important role in regulating serum cholesterol levels. Serum LDL of <130 mg/dl is desirable.

Some LDL oxidizes, which is usually scavenged by WBC. This scavenging releases cholesterol in vessel walls and over the years develops plaques inflicting atherosclerosis. This is promoted by smoking, diabetes, high blood pressure, high blood LDL levels and viral or bacterial infections. Consuming fruits and vegetables rich in antioxidants like vitamin C, vitamin E, carotenoids and certain phytochemicals inhibit LDL oxidation.

Liver and intestine produce another lipoprotein called *high density lipoprotein* (HDL). In blood, circulating HDL picks up cholesterol from dying cells and brings it back to liver for excretion. It is therefore referred as '*good*' cholesterol.

HDL also blocks oxidation of LDL. Serum HDL of > 50 mg/dl is cardio-protective and < 35 mg/dl indicates increased risk to heart diseases. Women, especially before menopause, have high HDL levels. Exercise and physically active lifestyle are sure ways of maintaining high HDL levels. Looking excess weight and avoiding smoking also maintains or raises HDL. Well-spaced meals keep serum triglycerides low and raise HDL. Serum triglycerides should be kept below 150 mg/dl. Raising HDL is more difficult than lowering LDL. Low fat diets and PUFA rich diets lower both HDL and LDL cholesterol. However, traditional low fat Asian diets result in low LDL and HDL and associated lower risk to heart diseases. More research is needed to validate long term implications. HDL/LDL ratio has been considered to be crucial in determining risk to heart disease. We will learn more about this aspect in the Clinical and Therapeutic Course (MFN-005) in Unit 12.

The discussion above was quite exhaustive. We hope having gone through this section and the unit on Lipid metabolism in the Nutritional Biochemistry Course, you would be quite clear about the mechanism of digestion, absorption and transport of lipids.

5.4 SOURCES OF FAT IN INDIAN DIET

The total fat intake of an individual comprise of the following:

- Invisible fat present in almost every food item
- Hidden fat in processed and ready to eat foods, and
- Visible fat (vegetable oil, ghee, butter and vanaspati) used for cooking.

A) *Invisible fat: Fats is present as integral component in plant and animal foods*

- *Edible plant foods* have a low content of fat and SFAs (except for nuts and oilseeds) and are fairly good sources of MUFAs and PUFAs. In most cereals, millets, legumes and pulses, fat content ranges between 1.5-3% (higher contents in maize, bajra, bengalgram and soyabean). In cereals, millets and most oilseeds, Linoleic acid (LA) is the major fatty acid whereas pulses / legumes, green leafy vegetables, some oilseeds (soyabean, rapeseed/mustard, flaxseed seed) and fenugreek are good sources of both LA and linolenic acid (ALA).
- *Animal foods* (fatty dairy products like butter, ghee, whole milk, cream, fatty cheese and fatty meats) provide cholesterol, high amounts of SFAs and are a natural source of TFAs. Structural fats (lean meats) have a fairly high content of long chain (LC) PUFAs. The meats of ruminants grazed on grass and in the wild contain less fat, SFAs and higher LCn-3 PUFAs (ratio of LCn-6PUFAs/LCn-3PUFAs is less than 2) as compared to meats of those in captivity fed on grain based rations. Poultry meat contains less fat and cholesterol but appreciable amounts of PUFAs including LC PUFAs. Egg has high cholesterol but is a good source of LA, ALA and DHA. Fish has less fat, SFAs and cholesterol and is a good source of LCn-3 PUFAs. Fat content and relative contents of EPA and DHA vary in fish and other sea foods.

B) *Visible Fat: present in vegetable oils, ghee, butter or any other oil used for cooking*

Depending on the percentage of various fatty acids, fats and oils can be grouped as oils containing: i) high SFAs ii) high MUFAs iii) low (40-70%) LA and iv) both LA and ALA.

Vegetable oil used in cooking is the major type of visible fat consumed; vanaspati (PHVO) and ghee are the other sources. India has a wide range of edible vegetable oils (groundnut, rapeseed/mustard, soybean, sunflower, sesame, safflower,

ricebran, cottonseed and linseed). The type of vegetable oil consumed varies from one part of the country to the other. Refer to Table 5.3 which presents the approximate fatty acid composition of dietary fats and oils consumed in India (% of total fatty acids). The traditional rape-mustard seed oils contain ~50% erucic acid (C22:1). Concerns about possible deleterious effects of erucic acid (lipidosis and fibrosis in experimental animals) in humans led to the development of low / zero erucic acid rapeseed variety and the oil is sold as canola oil. Butter, ghee, coconut oil and palm kernel oils are rich sources of short and medium chain SFAs. Vanasapti promoted as desi ghee is used largely in north India (Haryana, Punjab, Himachal Pradesh, Uttar Pradesh) as cooking medium.

Table 5.3: Approximate fatty acid composition of dietary fats and oils consumed in India (% of total fatty acids)

Fats/ oils	SFAs*	MUFAs**	LA	ALA
High medium chain SFAs				
Coconut	92	6	2	-
Palm kernel	83	15	2	-
Butter/Ghee	68	29	2	1
High SFAs & MUFAs				
Palmolein	39	46	11	~0.5
High MUFAs & Moderate LA				
Groundnut	19	41	32	~0.5
Rice bran	17	43	38	1
Sesame	16	41	42	~0.5
High LA				
Cotton seed	24	29	48	1
Corn	12	35	50	1
Safflower	9	13	75	-
Sunflower	12	22	62	-
LA and ALA				
Soybean	14	24	53	7
Canola	6	60 ^j	22	10
Mustard/rapeseed	4	65 ^k	15	14
Flaxseed	10	21	16	53
High TFAs				
Vanasapti	61	34 ^g	5	-

*SFA include < C10:0, C12:0 (lauric), C14:0 (myristic), C16:0 (palmitic), C18:0 (stearic)

** Mainly cis C18:1 (oleic) other MUFAs when present indicated against superscripts (Data from Indian Food Composition Tables - 2017); SFAs and MUFAs jC22:1 (erucic) ~2, kC22:1 (erucic) ~50 and C 20:1(gadoleic) ~ 5

Source: RDA and EAR – Nutrient Requirements for Indians. ICMR (2020)

Vegetable oils also contain minor components in the non-glyceride fraction which have specific health significance. The composition of non-glyceride components in dietary fats and oils is given in Table 5.4. Plant sterols and other unique components (oryzanols and sesame lignans) present in the non-glyceride component of vegetable oils contribute to lowering of total and low density lipoprotein cholesterol

- C) Hidden Fat:** In most parts of the country, sweets and savoury foods, commercially fried, processed, ready-to-eat, packaged, frozen, premixed foods and street foods are commonly consumed. Vanasapti is used as a substitute for ghee in preparing these foods and thus constitute the hidden fat. Partial hydrogenation of vegetable oils (PHVO) (vanasapti, bakery fats and margarines) is the main modifiable source of trans fatty acids (TFAs) in Indian diets.

Table 5.4: Non-glyceride components in dietary fats and oils and their health functions

Non-glyceride components	Oil	Biological and health function
Plant sterols	All vegetable oils	Hypocholesterolemic
Tocopherols	All vegetable oils	Vitamin, Antioxidant
Tocotrienols	Palm , Rice bran	Vitamin, Antioxidant
Carotenes	Red Palm	Provitamin, Antioxidant
Oryzanols	Rice bran	Hypocholesterolemic Antioxidant
Sesamin inflammatory	Sesame	Hypocholesterolemic Anti-
Sesamolin, Sesamol	Sesame	Antioxidant
Hydroxytyrosol, Phenolic acids	Olive	Antioxidant

Source: RDA and EAR – Nutrient Requirements for Indians. ICMR (2020)

Now, let us focus our attention on the functions of lipids in our body.

5.5 FUNCTIONS OF FATS AND FATTY ACIDS

In above sections, we have covered types and sources of fats and fatty acids. We have also understood how it is digested, absorbed and transported. Let us now know its routes of utilization and why body needs fats/fatty acid.

- 1) Fats contribute to *texture, flavour, taste and increases palatability* of the diet. They provide an effective medium of heat transfer in deep-frying and transfer of flavours from Indian spices.
- 2) Fatty acids are used for generation of cellular energy. It has highest *heat energy density of 9 Kcal/g*. It is the major storage form of energy in body requiring least space and minimum water of hydration as compared to protein in muscle or glycogen. Adipose cells are 80% lipid and only 20% water and protein.

In children's diet, cereals and pulses make their diet bulky. Fats are concentrated sources of energy. In adult's diet, use of visible fats should be minimum. Excessive fat intake is not recommended in any age, including children. The following section will detail on visible fat requirements, keeping in mind the invisible fat contents of Indian diets in all age group.

- 3) Fats are essential for *meeting nutritional needs of essential fatty acids* like linoleic acid (n-6)/(LA) and alpha linolenic acid (n-3)/(ALA). These fatty acids are used for biosynthesis of eicosanoids, membrane lipids and lipid mediators. They are essential for development of central nervous system and modulate lipoprotein metabolism. Let us look at these functions:

a) *Modulation of membrane structure and functions*

As the integral components of cell membranes, fatty acids affect membrane fluidity and lipid protein interactions which alter activity of membrane-related transport systems, ion channels, membrane bound enzymes, cellular receptors for hormones and neurotransmitters. AA and EPA of membrane phospholipids also give rise to an array of potent bioactive eicosanoids (thromboxanes, prostacyclins and leukotrienes). Eicosanoids derived from AA have strong pro-inflammatory, proaggregatory and vaso-constricting effects as compared to the opposing or weak effects of eicosanoids derived from EPA. PUFAs of n-6 and n-3 series and their metabolic products regulate production of lipid cellular mediators have potent anti-inflammatory effects and neuro-protective effects

b) *Role of AA and DHA in foetal and infant early growth and development*

During the foetal and early infant development, there is a rapid accretion of arachidonic acid (AA) and docosahexaenoic acid (DHA) in infant brain, DHA in retina and AA in the whole body for meeting the demands of rapidly growing tissues/organs. Small amounts of DHA are also present in cell membranes throughout the body. AA and DHA have different and specific roles in neural and behavioural functions. DHA is crucial for the function of rhodopsin for vision and postsynaptic receptors for neurotransmission. The foetus depends completely on the maternal source of LA, ALA, AA and DHA (maternal tissues/stores and dietary intake) and infant obtains these PUFAs through breast milk

c) *Role of dietary fatty acids in preventing coronary heart disease (CHD) and other diet-related non-communicable diseases (DR-NCD)*

Recent studies have shown that replacement of SFAs with PUFAs (LA, ALA, LC n-3 PUFAs) lower the risk of CHD and CHD events. Compared to higher fat intakes, diets low in fat with high carbohydrate result in a metabolic pattern that increases the risk of type 2 diabetes and CHD. The LC n-3 PUFA provided from fish and other sea foods lower serum triglycerides, postprandial lipemia and have beneficial effects on endothelial function, inflammation, vascular reactivity and ventricular arrhythmias. A strong inverse relationship is documented between fish or LC n-3 PUFA intake and CHD and some types of cancers

- 4) Fats promote *absorption of fat-soluble vitamins like vitamin A, D, E and K*. Patients of cystic fibrosis often absorb fat poorly and are at-risk for fat-soluble vitamin deficiency. Water miscible preparations of these vitamins are therefore prescribed.

Patients who are given mineral oil laxatives are at-risk of fat-soluble vitamin deficiency. The mineral oils carry these vitamins into large intestine which are lost in stool. Such laxatives should not be given at mealtime or for long periods.

- 5) Fat intake ensures *satiety*. It imparts feeling of fullness and satisfaction and thus delays onset of hunger. In low fat diets, satiety can be ensured by high fibre and fluid intake.
- 6) Fats along with proteins constitute *structural components of cell membrane and some body fluids*. Lipoproteins also have an important role in transport of lipids in blood.
- 7) Fats serve as *thermal insulator in the subcutaneous tissues and certain organs*. Some lipids act as electrical insulators allowing rapid propagation of depolarization waves along the myelinated nerves. The fat content of the nervous tissues is particularly high.

In anorexia nervosa, the body fat falls dangerously low (< 5%) shows problems in insulation. Body hair stands erect to trap air and simulate insulation.

- 8) *Nutritional and health promoting effects Of Non-glyceride components of fats:* Non-glyceride components of fats from animal foods contain cholesterol and fat soluble vitamins (A, E, D) whereas plant foods and vegetable oils have, in addition to fat soluble vitamins (E, D, K and carotenoids), plant sterols and a wide range of other chemical compounds. The composition and nutritional/health benefits of non-glyceride components in dietary fats and oils is given in Table 5.4. Plant sterols and some of the unique non-glyceride components (oryzanols and sesame lignans) lower serum LDL cholesterol. Vitamin E, carotenoids,

sesame lignans, oryzanols and polyphenols have antioxidant effects. Hypocholesterolemic and antioxidant effects of a combination of nonglyceride components are greater than their individual effects. Increasing plant sterols and other non-glyceride components from natural plant foods and vegetable oils could therefore provide an additional dietary means for prevention and correction of dyslipidemia and increasing antioxidant potential of human diets.

Unsaturated fats are susceptible to oxidation and rancidity. Most oils have natural antioxidants but food manufacturers have an option to add synthetic antioxidants like butylated hydroxyanisole (BHA) and butylated hydroxyl toluene (BHT) to prevent rancidity. One thing is for sure that vitamin E requirements of man are linked to PUFA intake. ICMR recommends vitamin E (tocopherol) at 0.8 mg/g PUFA intake.

Before we move on to our next section on nutritional requirements of fats and oils, let us recapitulate whatever we learnt till now.

Check Your Progress Exercise 2

- 1) Explain how lipids are digested in our gut.

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- 2) Briefly discuss the metabolic fate of triglycerides after the process of digestion.

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- 3) What do you understand by the term 'enterohepatic circulation of bile'? What is its significance?

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- 4) Why is LDL referred to as 'bad' cholesterol and HDL as 'good' cholesterol?

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5) Enumerate functions of lipids.

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5.6 NUTRITIONAL REQUIREMENTS OF FATS AND OILS

As with the other micronutrients, we do compute requirement of visible fat too for all age groups and give guidelines for selection of fats. For this we must consider total fat intake, which include both visible fat and invisible fat in food.

The total fat intake in the Indian population is income dependent and therefore highly skewed, the intake being low among rural and urban poor income groups. Diet surveys by the National Nutrition Monitoring Bureau show that daily intake of visible fats in rural India range 6-22g, median 13g/consumption unit and the diets of the rural population (including children, pregnant and lactating women) provide <14 % total fat calories. In the urban middle and upper income groups the daily intake of visible fat ranges between 22-45g/p/d and total fat in their diets furnish 20-33%E and show several risk factors of an early onset of heart disease.

The recommendations for dietary fats in Indians have been revised taking into account FAO and WHO recommendations, for: i) total fat, individual fatty acids and health promoting non-glyceride components ii) sources of dietary fats in Indians and iii) availability of fat and (iv) energy requirements set on the basis of age, physiological status and physical activity. The recommendations are directed towards meeting the requirements for optimal foetal and infant growth and development, maternal health and combating chronic energy deficiency (children and adults) and diet related Non-Communicable diseases (DR-NCD) in adults.

Let us look of fat requirement to meet minimum essential fatty acid requirement in all age group. Let us start with adults:

5.6.1 Adults

Taking into account 10 % E fat from all foods except visible fats; average of 7%E in rural India and 12 -14 %E in urban segments, unfavorable effects of low fat-high carbohydrate diets and depending on energy requirements set on the basis of physical activity, the minimal intakes of visible fat in Indian adults range between 20-40 g/ person (Table 5.5). A desirable amount of a linoleic acid (LA) to be consumed by a normal adult is 3 en%. There is a realisation that efforts to increase the dietary level of total fat and n-3 PUFA would contribute to life long health and well being inclusion of foods which provide n-3 PUFA is recommended for the prevention of DR-NCD.

Table 5.5: Recommendations for dietary fat intake in Indians

Age/Gender/physiological groups	Physical activity	Minimum level of Total fat (%E) ^a	Fat from foods other than visible fats %E	Visible fat	
				%E	g/d
Adult Man	Sedentary	20	10	10	25
	Moderate				30
	Heavy				40
Adult Woman	Sedentary	20	10	10	20
	Moderate				25
	Heavy				30
	Pregnant women	20	10	10	30
	Lactating women	20	10	10	30
Infants	0-6 months	40-60	Human milk	-	-
	7-24 months	35 ^b	10 ^c	25	25
Children	1-3 years	25	10	15	25
	4-6 years				25
	7-9 years				30
	10-12 years				35
	13-15 years				45
	16-18 years				50
Boys	10-12 years	25	10	15	35
Girls	13-15 years				40
	16-18 years				35
	16-18 years				35

a Reference : Joint FAO/WHO Expert Consultation on Fats and Fatty Acids in Human Nutrition, Interim Summary of Conclusions and Dietary Recommendations on Total Fat & Fatty Acids, November 10-14, 2008, WHO HQ, Geneva, accessed from <http://www.fao.org/ag/agn/nutrition/docs/Fats%20and%20Fatty%20Acids%20Summary.pdf>.

5.6.2 Pregnant and Lactating Women

The minimum level of total fat should be 20%E. Adult pregnant and lactating females, should consume at least 200mg/d DHA for optimal adult health and fetal and infant development. To furnish 20 %E total fat, diets of pregnant and lactating women should contain at least 30 g visible fat (Table 5.3). Linoleic acid requirement should be raised to 4.5 en% during pregnancy. This can be met from 30g/d of oil which has >20% linoleic acid. Similarly, linoleic acid requirement during lactation rise to 5.7 en%.

5.6.3 Infancy

Infants (0- 6m): The recommended method of feeding healthy infants is breast milk. The fat content of human milk is relatively constant at 3-4% by weight and delivers 50-60% E. adequate breastfeeding ensure 30 g fat intake by infants, of which 10% is linoleic acid and 1% linolenic acid. Breast milk thus meets EFA needs of infants of 6 en%. Human milk substitutes / infant formulas should have fat and individual fatty acid contents (including AA and DHA) similar to the levels in human milk. Preterm infants have a higher requirement for AA and DHA to allow rapid brain and body growth.

Infants (6-24 m): From age 6 months to 2 years, fat intake should be reduced gradually, depending on the physical activity of the child, to 35%E. The mix of fat from breast milk and complementary foods should provide infants with at least 3–4.5%E from LA and 0.4-0.6 % E from Alpha Linoleic Acid (ALA). In situations where breast milk intake is low, the level of fat, LA and ALA in complementary foods should be increased so as to achieve the recommended intakes. To provide optimal energy density and adequate calories, young preschool children's diet should carry enough fat. Assuming 10%E fat from breast milk and / infant formula plus fat from complementary foods (except visible fat), 25 g visible fat is recommended in diets of young children (Table 5.3).

5.6.4 Children and Adolescents (2-17 y)

Total fat intake below 25%E is considered to affect growth in children and adolescents. To provide 25% total fat calories, the minimum level of visible fat in children and adolescents should range between 25-30 and 35-50g / day respectively (table 5.3). Since the requirement of fatty acids for adolescents has not been adequately established, the recommendations for this age group are set to be the same as in adults.

5.6.5 Choice of Cooking Medium in the Context of n-3 and n-6 Fatty Acid Ratio in Indian Diets

A cooking medium should meet EFA needs. Some EFA will come from invisible fat. Selecting an oil with at least 20% linoleic acid is not the only criteria. ICMR (1998) has given dietary guidelines to maintain n-6 / n-3 ratio of 5-10:1, which ensures long-term health. However, most oils are rich in linoleic acid (n-6). Consumption of PUFA rich oils lead to a very high ratio. Excess n-6, impairs desaturation and elongation of linolenic acid to EPA and DHA, which is best avoided. It is, therefore, important to promote linolenic acid (n-3) intake to balance the ratio. For ensuring the appropriate balance of fatty acids in cereal-based diets and in the diets of those who do not eat fish and are primarily vegetarians like in the case of many Indian diets, we need to depend on plant foods rich in linolenic acid.

WHO/FAO Expert Group on Diet, Nutrition and Prevention of Chronic Diseases endorsed that qualitative composition of fats in the diet has a significant role to play in modifying risk factors of CVD and set the following ranges for population nutrient goals (%E):

- Total fat, 15-30 (at least 20% E is consistent with good health),
- SFAs, <10%;
- PUFAs, 6-10; n-6, 5-8; n-3, 1-2; n-6 to n-3 ratio between 5-10:1
- TFAs, < 1; MUFAs, by difference;
- Cholesterol <300mg/d.

To achieve intakes of individual fatty acids in the diet that are consistent with recommendations (Table 5.5); the types of visible fats and correct combination of vegetable oils to be used for different food applications are summarized in Table 5.6

It is strongly recommended that more than one source of cooking oil should be used in every household. For this reason, blending of oil is not the best option.

Recently, blending of oil has been popularized for healthful gains, acceptability and equalizing SFA: MUFA: PUFA to 1:1:1. Blending rice bran oil with safflower oil in ratio of 7:3 is very promising, since it magnifies the hypocholesterolaemic effect than effects of individual oils. Similarly, blending of palm oil with rice bran oil in a ratio of 3:1 ensure SFA:MUFA:PUFA of 1:5:1 which is effective in preventing heart disease according to American Heart Association and Japanese Ministry of Health and Welfare.

Table 5.6: Recommendations on type of visible fat

1	Use correct combination / blend of 2 or more vegetable oils (1:1)
	Oil containing LA + oil containing both LA and ALA
	Groundnut / Sesamea / Rice branb / Cottonseed + Mustard/ Rapeseed
	Groundnut /Sesamea / Ricebranb / Cottonseed + Canola
	Groundnut / Sesamea / Rice branb / Cottonseed + Soyabean
	Palmoleinc+ Soyabean
	Safflower / Sunflower + Palm oil/Palmoleinc + Mustard/ Rapeseed
	Oil containing high LA + oil containing moderate or low LA
	Sunflower / Safflower + Palmoleinc / Palm oilc / Olive
	Safflower / Sunflower + Groundnut / Sesamea / Ricebranb / cottonseed
2	Limit use of butter/ghee
3	Avoid use of PHVO as medium for cooking / frying
4	Replacements for PHVO Frying : oils which have higher thermal stability — palm oil / palmolein , sesame , ricebran , cottonseed — single / blends (home /commercial) Bakery fat, shortening, Mithai / Indian sweets etc — Food applications which require solid fats : coconut oil/ palm kernel oil/ palm oil / palmolein/ palm stearin and / their solid fractions and / their blends

Let us take a break here and recall what we have learnt so far.

Check Your Progress Exercise 3

- 1) Give the EFA requirements during:
 - a) adulthood
 - b) pregnancy and lactation
 - c) infancy
 - d) Youn children
- 2) What are the recommendations put forth by ICMR for choosing cooking oil?

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- 3) What are these benefits of blending oils? Which oils are generally blended?

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In the section above, we learnt about the fat requirements and the best possible fat/oil options to meet our requirements. If our intake exceeds the recommended requirements, what will happen? Read and find out next.

5.7 EXCESSIVE FAT INTAKE

Although minimum amount of fat is essential as calculated above but upper limit of fat should be drawn due to its link with an increased risk of developing obesity, heart diseases and cancer. The fact that these diseases are on a rise can be attributed to the changing dietary and lifestyle practices coupled with stress. Let us look closely at these factors.

5.7.1 Changing Trends in Dietary Intake

As a practicing dietitian, you must be sensitive to the society as a whole. The fat requirements have been worked out with a premise of traditional moderate cost Indian diet. Contemporary society showing nutritional transition and access to fast foods and fried snacks while eating out is in vogue. This leads to an increased intake of saturated fatty acid, milk and milk products, flesh foods and sugar at the cost of whole cereals, millets and pulses. This is likely to decrease EFA intake from invisible sources and raise SFA. The total calories are also high, especially if alcohol consumption is also on a rise. Check out the facts by doing the following assignment/exercise.

Assignment

A young employee in a multinational company consumes no breakfast but samosa and coffee in midmorning, a pizza and ice cream for lunch, biscuit and coffee twice in office before going home to eat a traditional Indian meal. The fatty acid analysis of whole diet reveals presence of 20 g SFA, 10 g MUFA and 50 g PUFA in 1900 Kcal daily intake.

Now calculate the following:

SFA en%.....

MUFA en%.....

PUFA en%.....

Total fat en%.....

SFA:MUFA:PUFA

Now Comment:

- 1) Which of the three types of fatty acids need attention?

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- 2) Suggest some useful dietary modification looking at his lifestyle.

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Having looked at the changing trends in dietary intake, let us study about eating out as a factor contributing to excessive fat intake.

5.7.2 Eating Out

This is emerging as the most common factor associated with obesity, excessive fat intake and total caloric intake. When we closely look at the selection of foods while

eating out, they are mostly fried snacks and dishes, like South Indian *dosa*, *Vada*, or North Indian *chole-bhature* or fried Chinese. Fried snacks like samosa, bread roll, bread pakora, paneer pakora, and aerated beverages are usually supplied in all canteens. Namkeens and chips also contain 20-70% fat. These foods could be best avoided. Table 5.7 suggests some tips in food selection.

Table 5.7: Tips to reduce fat intake

1)	Avoid baked foods except bread. Avoid buttered toasts. Avoid eggs as they are rich in cholesterol.
2)	Prefer salads with lemon dressing.
3)	Reduce number of cooked preparations. Each Indian preparation needs a lot of fat.
4)	Modify standard Indian recipe for low fat cooking. Use non-stick pan, less greasy gravy and topping of extra ghee. Dry roast instead of using plenty of ghee etc.
5)	Limit non-vegetarian eating, prefer fish.
6)	Prefer skimmed milk, even in yoghurt, cottage cheese etc.
7)	Avoid eating out on a regular basis or purchasing food. Do not select fried foods, pizza with extra cheese, creamed soups, fried rice and noodles.
8)	When eating out, keep in mind hygienic handling and select soups (no cream or butter), sprout salads, fruits, cocktails.
9)	Prefer cooking methods like steaming, boiling, stewing. Avoid sauté, fry or creamed. Indian curry making is in fact frying of onion, ginger and garlic paste and use of good amount of fat.
10)	Among desserts, prefer fresh fruit and non-thickened milk puddings made from skimmed milk. Avoid pastries, ice creams, egg custard, kheer, kulfi etc.
<i>Aim to eat no more than 3 tsp of fat per day through cooking.</i>	

We have already discussed that fried foods and baked products could be a source of trans-fatty acids (sub-section 5.3.1). Further, quality and source of frying oil is not known. May be the oil used is highly reused and abused. Rice bran oil and palm oil gives a slightly lower oil uptake than other oils. Yet it is better to select dishes prepared by other cooking methods than frying for lesser oil intake. *Dish selection and behaviour modifications* are the key words in commercial business of weight reduction clinics.

Excessive consumption of fat can lead to various harmful health effects. What are these? The next sub-section focuses on these health effects.

5.7.3 Diseases: Association and Preventive Measures

By now, you must have realized that excessive consumption of fat can lead to various harmful health effects. Well, three diseases have shown close link to excessive dietary fat intake: *obesity*, *heart diseases* and *cancer*. Let us see how are these related and their onset can be prevented.

- *Obesity*

In obesity, cutting down total energy intake or increasing output to ensure energy balance is the basic principle of prevention. Fat being energy dense is always on the hit list. Tips of fat reduction are given in Table 5.7. This will help you to counsel all such patients. Selection of foods and modified cooking methods further prevent excessive fat intake. Low fat diets should be given with high fibre and fluid diet to ensure compliance and satiety.

- *Heart Diseases*

Heart diseases show strong links to fat and cholesterol intake. Foods rich in cholesterol are of animal origin and given in Table 5.8. Higher dietary cholesterol increases blood

cholesterol but high blood cholesterol with family history does not necessarily gain on cholesterol-free diet. Both drug and low cholesterol diet is recommended. *Vegetable oils have no cholesterol*, as can be noted from Table 5.8. The reference of ‘good’ and ‘bad’ cholesterol to dietary fats is in reference to the effect in blood lipids and HDL/LDL ratio. The significance of n-6/n-3 ratio has been already covered in previous sections. High intakes of n-6 polyunsaturated fats have been associated with the reduced total cholesterol and LDL cholesterol concentrations that are associated with low risk of CHD. In general, epidemiological studies have demonstrated an inverse association between n-6 polyunsaturated fatty acid intake and risk of CHD. n-3 polyunsaturated fatty acids (particularly, eicosapentaenoic acid [EPA] and docosahexaenoic acid [DHA]) have been shown to reduce the risk of CHD and stroke by a multitude of mechanisms: by preventing arrhythmias, reducing atherosclerosis, decreasing platelet aggregation, lowering plasma triacylglycerol concentrations, decreasing proinflammatory eicosanoids, modulating endothelial function and decreasing blood pressure in hypertensive individuals.

Table 5.8: Cholesterol content of foods (in descending order)

Food	Cholesterol (mg/100 g)
Egg yolk	1500
Egg whole	550
Kidney	375
Liver	300
Butter	250
Lobster	200
Shrimp	125
Crab	125
Cheese, Cream	120
Cheese, Cheddar	100
Milk powder (whole)	85
Pork	70
Lamb	70
Fish	70
Cheese spread	65
Mutton	65
Ice cream	45
Cheese, cottage	15
Milk, whole	11
Milk, skim	3
Vegetable oils	0

ICMR further suggests:

- Just take enough fat (as per the RDA),
- Use more than one source of cooking oil,
- Limit use of ghee, butter and vanaspati,
- Eat linolenic acid rich foods like green leafy vegetables, spices like fenugreek seeds and mustard seeds in a predominantly cereal pulse diet,
- Eat fish more frequently than meat and poultry,
- Limit and avoid organ meats like liver, kidney and brain,
- Skimmed milk and low fat milk is preferred instead of whole milk.

- *Cancer*

Role of fat in cancer is debatable. High fat intake is indicated as a risk factor to cancer of breast, colon etc. Saturated fat intake has been implicated more in cancer events. Abused oil intake (re-used oil) and oils with high peroxidative potential producing free radicals in body also promote carcinogenesis. Look up Unit 9 in the Nutritional Biochemistry Course (MFN-002) for more information on free radicals. The unsaturated fatty acid consumption should not be indiscreetly promoted in absence of relevant research data. The PUFA intake should not exceed 10 en%.

With this, we come to an end on our discussion on lipids, its types and sources. We hope that this unit will have brought up issues related to fats and oils which will definitely help you out as a dietitian.

Check Your Progress Exercise 4

- 1) Enumerate a few handy tips to reduce fat intake.

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- 2) How is high fat and cholesterol intake related to heart disease? List five items rich in cholesterol.

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- 3) Give American Heart Association and ICMR (2010) guidelines for the prevention of heart disease.

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- 4) What is the role of high fat intake in promoting carcinogenesis?

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5.8 LET US SUM UP

In this unit, we learnt about the classification of fats, the major difference between fats and oils and the concept of visible and invisible fats. We saw that man primarily consumes triglycerides. Diets also provide cholesterol, which is present only in foods of animal origin.

We then learnt about lipid digestion and absorption, where we discussed that long chain fatty acids, cholesterol and phospholipids are absorbed through the lymphatic

vessels only after emulsification by bile. Short and medium chain fatty acids are absorbed directly into blood. We also get to know about 'good' and 'bad' cholesterol. The good cholesterol or HDL is cardio-protective and can be raised by exercise, avoidance of smoking, maintaining normal weight and eating pattern. Consumption of fruits and vegetables inhibits LDL oxidation and in turn, prevents cholesterol deposition. Fats have an important role in human nutrition and some amount of it should be present in daily diet. Use of 2-3 different oils per household is recommended. Eating out often must be avoided as it leads to an increase in consumption of fats especially trans-fatty acids.

Finally, we learnt that excessive fat intake could lead to major health diseases such as obesity, heart diseases and cancer. Hence, a judicious fat intake with a healthy life style and correct eating habits must be chosen to prevent the risk of these diseases.

5.9 GLOSSARY

Chylomicrons	: water miscible lipoprotein molecules.
Compound lipids	: simple lipids which combine with other molecules such as proteins, carbohydrates and phosphates.
Derived lipids	: fatty lipids, glycerol, cholesterol and other derived compound.
Essential Fatty Acids (EFA)	: those fatty acids that cannot be synthesized in body and are needed in daily diet. Linoleic acid and linolenic acids are two essential fatty acids.
Fats	: triglycerides made up of saturated fatty acids which are liquid at room temperature.
Invisible fats	: fats that are present as an integral component of different foods such as milk, meat, egg, cereals, pulses etc.
Linoleic acid	: an EFA; also called Lin or LA content of fats. Chemically, it is omega-6 (n-6); C18:2, cis-9, 12 octadecenoic acid.
Linolenic acid	: an EFA also, called Len content of fats or ALNA (alpha linolenic acid). Chemically, it is omega-3 (n-3), C18:3; cis 9, 12, 15 octadecenoic acid.
Lipoprotein	: any particle in blood containing a core of lipids with a shell of protein. It can freely move in an aqueous medium of blood.
Simple lipids	: fatty acid esters of glycerols or higher alcohols.
Trans-fatty acid	: all naturally occurring fats in the body are cis isomers. Trans-isomers differ in structure and properties but have same formula.
Triacylglycerol	: also called triglyceride. Acyl stands for fatty acids hence three fatty acids esterify three alcohol groups of a glycerol molecule to form triglyceride or triacylglycerol.
2-monoacyl glycerol	: has single fatty acid which esterify only second carbon of glycerol.
Visible fats	: fats that are used as such at the table or for cooking. They are of both plant and animal origin.

5.10 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

- 1) Body fat is considered a predictor of storing unused fuels when energy intake exceeds energy expenditure. It is measured to monitor the level of physical fitness in case of sport subjects.

Skin fold method and impedance method are used to measure BF%. It is calculated as:

$$\text{BF\%} = \frac{\text{Fat mass (kg)}}{\text{Body weight (kg)}} \times 100$$

- 2) Visible fats are the fats and oils used as such at the table or used for cooking, such as salad dressing, mayonnaise, butter, cream, vegetable oils, ghee etc. While invisible fats are present naturally as an integral component of different foods such as flesh foods, whole milk, peanuts, soyabean, nuts and oilseeds etc.
- 3) Lipids are classified as simple lipids, compound lipids and derived lipids.

Simple lipids – fats and oils

Compound lipids – lipoproteins, glycolipids and phospholipids

Derived lipids – fatty acids, glycerol, cholesterol, fat soluble vitamins hormones and bile.

- 4) Fatty acids which cannot be synthesized by the body and need to be taken from the diet for e.g. linoleic and linolenic acid.

They are part of vital body structures, perform important role in immune system, formation of cell membrane and produce hormone-like compounds. These compounds are potent regulators of vital body functions like blood pressure, child birth, blood clotting, immune response, inflammatory responses and stomach secretions.

- 5) Trans-fatty acids are produced when vegetable oils are hydrogenated to make margarines, partially hydrogenated vegetable shortening and vanaspati. Its sources are commercially baked products, deep fried snacks in vanaspati and mithai.

Check Your Progress Exercise 2

- 1) The enzyme lipase secreted by stomach and pancreas hydrolyzes nearly 30% of triglycerides comprising of short and medium chain length fatty acids. These then get absorbed through stomach wall into portal vein. Long chain fatty acids entirely depend on emulsification by bile in gut. Pancreatic lipase hydrolyzes ester linkages in a triglyceride. After this action, mixture of products is obtained for absorption in jejunum.

- 2) The major digestion products left are 2-monoacylglycerol, fatty acids and 1-monoacylglycerol, diffuse micelles consisting of bile salts, lecithin and cholesterol into aqueous phase of intestinal lumen towards brush border of the mucosal cell.

The utilization of free fatty acids is by activation of fatty acids and glycerol inside the mucosal cell to resynthesize triacylglycerol. These triacylglycerols and phospholipids, cholesteryl esters, cholesterol and small amount of protein form chylomicrons. Hence, long chain fatty acids of more than 10 carbon chain, phospholipids and cholesterol are absorbed in lymphatic vessels.

- 3) Bile itself undergoes reabsorption to be recycled 6-10 times a day. This is referred to as enterohepatic circulation of bile. Its excretion is important for eliminating endogenous cholesterol.

- 4) LDL contains all the cholesterol present in VLDL having therefore a higher cholesterol/triacylglycerol ratio rather than VLDL and IDL. LDL is therefore referred to as bad cholesterol and is strongly associated as a risk factor of heart diseases. While in blood, circulating HDL picks up cholesterol from dying cells and brings it back to liver for excretion. It is therefore referred as good cholesterol.
- 5)
 - Contribute to texture, flavour, taste and increases palatability of the diet.
 - Major storage form of energy in body.
 - Essential for meeting nutritional needs of EFAs which are needed for synthesis of important eicosanoids.
 - Promote absorption of fat-soluble vitamins.
 - Ensures satiety, imparts feeling of fullness and satisfaction and delays onset of hunger.
 - Constitutes structural components of cell membrane and some body fluids.
 - Serves as thermal insulator in subcutaneous tissue and certain organs.
 - Contains antioxidants which confer stability to the oil and prevent rancidity.

Check Your Progress Exercise 3

- 1)
 - a) Visible fat which contains at least 20% linoleic acid. Viewing 10 en% from invisible fat in diet, the remaining 5 en% can come from visible fat, which has more than 20% linoleic acid. This 5 en% in 2400 Kcal diet works out to be 12 g/day. This implies that even 3 tsp of cooking oil/ table fat a day meets adult requirements.
 - b) Linoleic acid requirements raises to 4.5 en% during pregnancy. This can be met from 30 g/d of oil which has >20% linoleic acid.
Linoleic acid requirement during lactation raises to 5.7 en% which corresponds to 45 g oil intake which has >20% of linoleic acid).
 - c) Adequate breast-feeding ensures 30g fat intake by infants, of which 10% is linoleic acid and 1% is linolenic acid. Breast milk thus meets EFA needs of infants of 6 en%.
 - d) 3 en%, which would be met from 8-10 g of oil. ICMR (2010) recommends 20 g/d in children's diet from oil which has at least 20% linoleic acid.
- 2) The ICMR recommendations for the choice of cooking oil is given in sub-section 5.5.5. Read and write the answer on your own.
- 3) Blending of oil has healthful gains, acceptability and helps in equalizing SFA: MUFA: PUFA to 1:1:1. It magnifies the hypocholesterolaemic effect and effective in preventing heart diseases. Rice bran oil is blended with safflower oil (7:30) and palm oil with rice bran oil (3:1).

Check Your Progress Exercise 4

- 1) Tips to reduce fat intake are given in sub-section 2.6.2 in Table 5.4. Write the tips on your own.
- 2) Heart diseases show strong links to fat and cholesterol intake. Higher dietary cholesterol intake increases blood cholesterol. Egg yolk, egg whole, kidney, liver, butter are rich in cholesterol.
- 3) The American Heart Association and ICMR guidelines are included in sub-section 5.6.3. Read and write on your own.
- 4) High fat intake and saturated fat intake has been implicated as a risk factor to cancer events. Abused oil intake and oils with high peroxidative potential producing free radicals in body promote carcinogenesis.